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SUNSPACES

A MONTANA GUIDE

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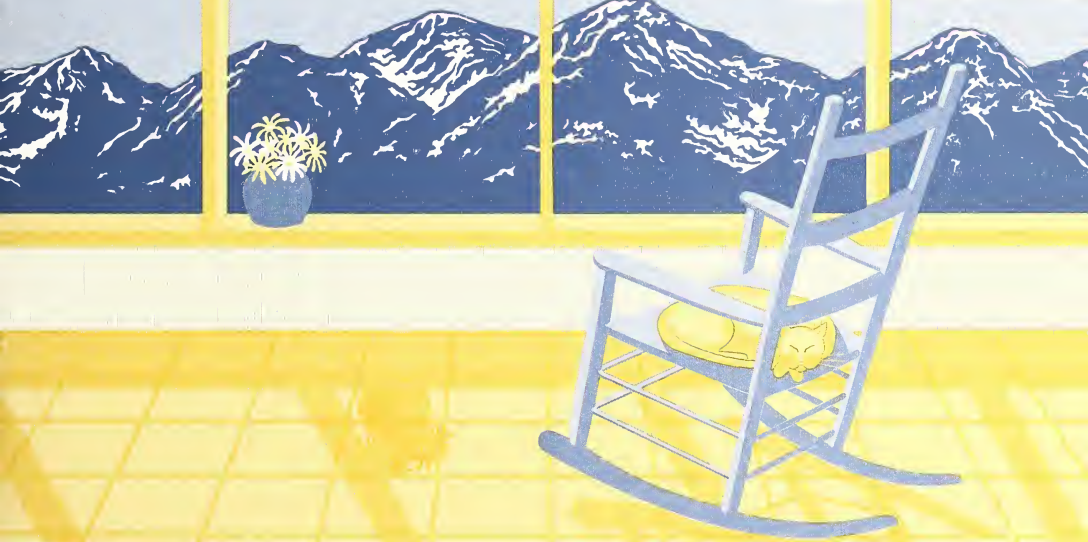

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SUNSPACES

A Montana Guide

Energy Division
Department of Natural Resources
and Conservation
Capitol Station
Helena, MT 59620

October 1985

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WHAT'S A SUNSPACE?

Sunspaces—sunrooms, sun porches, solaria, and greenhouses—are today's most popular solar devices. Other solar devices cost less and bring more heat into your home than a sunspace would, but they can't double as a warm, sunny retreat on a cold, winter day. Throughout Montana, in cities, small towns, and rural areas, you'll find homeowners enjoying sunspaces. Montanans are using sunspaces as sunrooms, hot tub enclosures, sources of light for nearby rooms, greenhouses, or a combination of these.

Your sunspace could be a simple, small, enclosed porch like the one Angie Leprohon and David Nimick built on their home. They decided they didn't need a year-round sunspace, so they built a "portable sunspace" which attaches to the front porch in the fall, and comes off in summer. On the other hand, Rich and Gigi Moy chose to go all-out when building their new home. The Moys built a two-story greenhouse and sunspace, with an elaborate ventilation system to automatically channel warmed air into their house on cold days.

Both couples are enthusiastic sunspace supporters. Even though their sunspace has more air leaks than they'd like, Leprohon and Nimick have noticed a big difference in winter heating comfort since they installed their "instant sunspace." Rich Moy's January electric bills have been under $60.00. He thinks his bill is this low partly because of the sunspace.

This guide will help you decide if a sunspace suits your lifestyle and wallet by discussing the pros and cons of different sunspace designs, the basic components, and how to capture as much solar heat as possible. It won't answer all your questions, so check the Information Sources section at the end of this publication. Talk to builders and to your friends who have sunspaces. Then, if you're convinced a sunspace is for you, go to it!

IS A SUNSPACE RIGHT FOR YOU?

What kind of sunspace do you want? The answer will depend on how much you want to spend, what kind of home you have, and how you plan to use your sunspace. You can build a fairly inexpensive sunspace, but a survey by the New York State Energy Research and Development Authority (1983) showed a direct correlation between owner satisfaction and the cost of a sunspace. The more owners spent, the more satisfied they were with the results. If your purpose is growing plants, you might spend less than you would for an attractive living space. You don't have to spend a fortune to get a sunspace you'll be happy with, but extra time and money spent planning and constructing your sunspace can prevent serious problems later.

First, determine if the location and style of your home will allow you to add a sunspace. Local zoning codes may forbid a sunspace built too close to property lines. A good, south-facing exposure (one within 30 degrees of true south) is necessary; without it, your sunspace may not provide solar heat to your living area on cold days.

The way you intend to use your sunspace should determine its design. Sunspaces can provide your house with heat, additional living space, and a sunny place to sit, or you might want your sunspace to be a greenhouse. "Adding a greenhouse to get a place for plants and 'free heat' for the house obscures a complicated design problem," says Bozeman engineer Charless Fowlkes. "Plants have one set of requirements for temperature, humidity, and light, and people have different requirements. Connecting the greenhouse and the 'peoplehouse' in a mutually satisfying way requires careful design."

THINKING THROUGH THE DESIGN

Sit down with pencil and paper, and sketch out your "dream sunspace." Have fun with it. How about a hot tub or an indoor rock garden? Next, draw what you can afford for now, keeping your extravagant ideas in mind. Leave room in the plans for your dreams, so someday you can turn them into reality.

Perhaps you can only afford a basic sunroom now. However, if you put in plumbing connections now, you might eventually add that hot tub. If you don't plan ahead, you might have to dig up your floor to add plumbing later. Refine your ideas until you know exactly how your sunspace will look when it's completed. A good rule of thumb is that every hour spent designing your sunspace saves five hours of construction labor.

Early in the planning, check building codes and zoning regulations; you'll probably need a building permit before construction. Don't wait until your sunspace is built to discover that it doesn't meet building or fire codes, or it's two feet beyond your property line.

BUY IT PREFABRICATED OR BUILD IT ON?

Building even a simple sunspace is more work than you may think. If you're handy with masonry, carpentry, and glazing, then building it yourself may save money. A simple sunspace of inexpensive materials is easier to build than one requiring a new foundation, complex ventilation, and professional construction. Assess your skills and the complexity of the construction before plunging into this building project.

What if you'd like a sunspace, but don't want to worry about the construction? You've got two options. Have a qualified builder design and construct your sunspace on-site, or purchase a prefabricated sunspace.

Site-built sunspaces generally cost less than prefabricated structures, even if you have contractors build it for you. By building your own sunspace, you can design it to fit your site and lifestyle perfectly. However, you'll have to invest a lot of time in supervising construction, approving designs, and checking on construction quality. Many builders and architects in Montana specialize in solar construction and can give you ideas. If you have the sunspace built, take the precautions you would in choosing a contractor to build your home. Get estimates from builders, check their references, and talk to their previous customers. Although it will take more time to compare contractors, chances are you'll be happier than if you hadn't checked around.

If you'd prefer to buy a prefab sunspace, the May 1985 issue of *Solar Age* has a review of over twenty prefab manufacturers. Prefab sunspaces are often attractive, easily installed, and available in a variety of styles. However, prefabs may not match your site requirements, fit your budget, or be available in Montana.

If you're going to buy a prefab sunspace, get a system that is well constructed, has good installation instructions, is guaranteed or well-supported by the manufacturer or dealer, and blends in with your home. Make sure you understand what comes with the kit: most offer glazing, framing, and vents, but few kits include the floor or foundation. Costs for a delivered prefab kit range from $10.00 to $80.00 per finished square foot of floor area.

WHAT'S SO SPECIAL ABOUT A SUNSPACE?

A sunspace isn't an ordinary house addition. It's a solar collector, too. Sunspace features, illustrated in figure 1, work to collect and retain heat.

Special Features of Sunspaces

1. **South-facing glass** or plastic glazing admits maximum solar energy.
2. **Heat storage (thermal mass)** absorbs solar heat and releases it when needed, at night or on cloudy days.
3. **High levels of insulation** and leakproof construction reduce heat loss.
4. **Windows, doors, vents, or fans** used alone or together distribute heat from the sunspace to nearby rooms.
5. **Vents, shades, and overhangs** regulate incoming solar heat to prevent overheating the sunspace in summer.

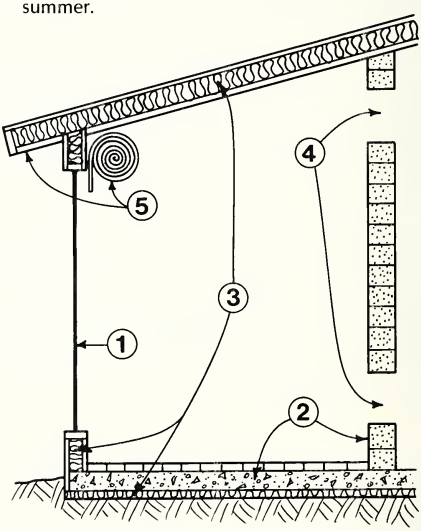

Figure 1. Sunspace features:

1) South-facing glazing
2) Thermal mass
3) Insulation
4) Vents for heat distribution
5) Shading devices

SOUTHERN EXPOSURE IS BEST

Your sunspace should face true south as closely as possible to gather the maximum amount of solar heat.

True south differs from magnetic south, which means a compass reading of south isn't accurate for siting a sunspace. As shown in figure 2, true south in Montana varies from 14 to 21 degrees east of magnetic south.

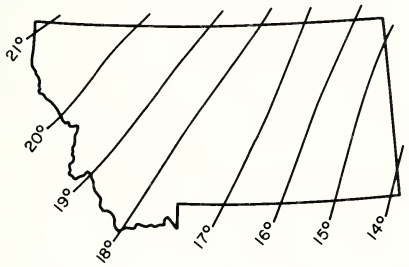

Figure 2. Montana's magnetic south deviation from true south

You can find true south on a sunny day with a watch, a pencil, and a protractor. If you have no protractor, the drawing in figure 3 can be substituted for it.

First, find out when solar noon is. Check the newspaper or call the weather service to find the exact time of sunrise and sunset on the day you wish to determine solar noon. Since solar noon is exactly halfway between sunrise and sunset, you can calculate it as follows:

Example: On the day of your test, sunrise is at 5:30 A.M., and sunset is at 8:00 P.M. What time is solar noon?

Solution: Calculate the number of hours and minutes between sunrise and sunset (in this case, 14 hours and 30 minutes), and divide by two (7 hours and 15 minutes). Solar noon is 7 hours and 15 minutes after sunrise, or 12:45 P.M.

At exactly solar noon, lay the protractor's straight side against what you believe to be a south-facing window (figure 4). Then, stand a pencil upright in the center of the protractor's straight edge. The pencil's shadow at solar noon is a true north-south line. The shadow on the protractor falls across the angle that your wall is "off" true south.

If your pencil's shadow is perpendicular to the protractor's straight edge, as shown in figure 4, you have a true south wall for a sunspace. Don't be discouraged if you don't have a true south wall; a wall

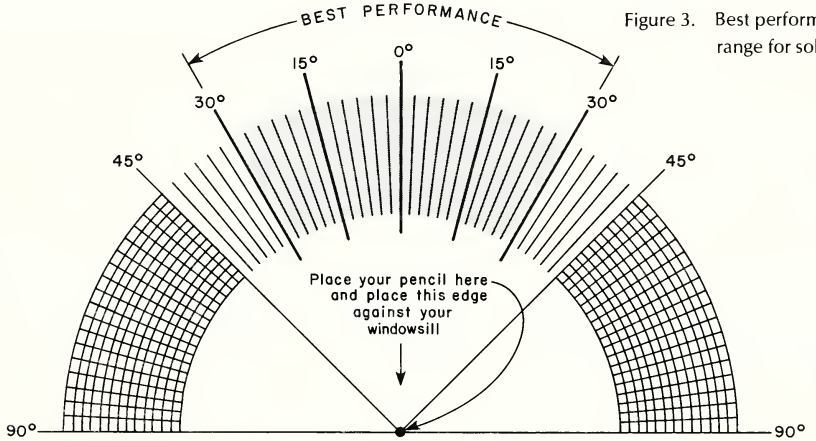

Figure 3. Best performance range for solar gain

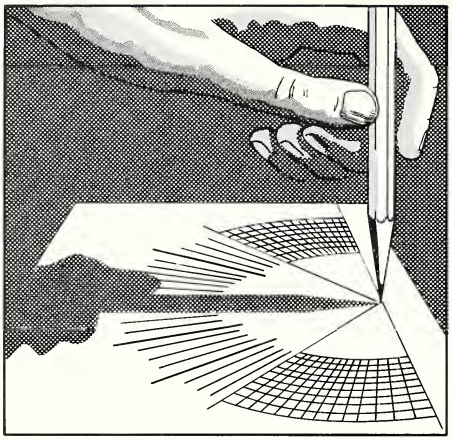

Figure 4. Checking solar orientation

within 30 degrees of true south still gains about 90 percent of the available solar radiation (figure 5). If your wall is more than 30 degrees from true south, a sunspace there wouldn't gain much solar heat, and perhaps you should reconsider your plans. The pencil's shadow should fall within the shaded area shown in figure 3 for good solar gain.

WHAT TYPE OF GLAZING?

Proper glazing is crucial to gathering the maximum amount of sunlight. Glazing can also be the downfall of sunspaces. According to *The Sunspace Primer* (Jones and McFarland 1984), "The largest single sunspace heat loss is through glazing. It is normally larger than all other losses combined." Two things make the difference between a sunspace that works well and one that's an energy-loser: a high-quality glazing that transmits as much solar energy as possible, and a system that loses as little heat as possible.

Deciding which glazing to buy can be confusing; it ranges from inexpensive polyethylene sheets to expensive, triple-glazed, tempered glass. Your glazing decision will depend on your sunspace's function. Keep in mind that any single thickness glazing loses more heat than it gains during the winter. Even a double-thickness of glazing usually loses more heat than it gains during December and January. A third layer of glazing would again reduce your heat loss, but the extra cost may not make it worthwhile.

Checking transmittance and "U-values" could help you choose between glazings. Only part of the solar energy striking the glazing will enter the sunspace, which is a glazing characteristic called transmittance. The actual transmittance of your glazing at any time depends on the glazing material, its thickness, the angle of the sun's rays, the cleanliness of the window, and shading such as trees and curtains. Table 1 lists the transmittance values of some glazings.

The U-value is the heat loss rate per square foot for each degree difference between the inside and outside temperatures. The lower the U-value, the better the glazing is at preventing heat loss. Typically, double glass has a U-value between 0.49 and 0.57, depending on the width of the air gap between the panes. Table 1 also lists the U-values and other qualities of various glazings.

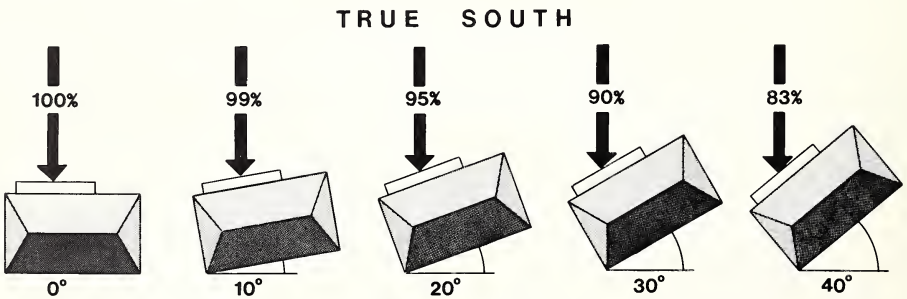

Figure 5. Solar gain decreases with deviation from true south

Table 1. Comparisons of Glazing Types

GLAZINGS	U-VALUE	TRANSMITTANCE VALUE	COST	COMMENTS
Polyethylene Sheet	1.60	0.85	Least expensive	Installs easily, loses heat easily, is not durable, prone to rips and tears
Single-layer, fiberglass-reinforced plastic (FRP)	1.00	0.82	Inexpensive	Cuts to size easily, provides good transmittance, loses heat easily, needs recoating in four to six years, surface roughens
Double-layer, fiberglass-reinforced plastic (FRP)	0.41	0.75	Inexpensive	Cuts to size easily, doesn't lose heat as easily as a single layer, provides good transmittance, needs recoating in four to six years
Single-layer plexiglass (acrylic)	1.00	0.92	Inexpensive	Provides good transmittance, retains heat fairly well, yellows over time but not badly, can shatter
Double-layer plexiglass (acrylic)	0.55	0.82	Inexpensive	Provides good transmittance, retains heat fairly well, yellows over time, can shatter
Double-glazed polycarbonate	0.52	0.74	Moderately expensive	Retains heat better and is stronger than plastics, poor transmittance that decreases over time as the polycarbonate yellows, the yellowing could slow plant growth
Triple-glazed polycarbonate	0.38	0.67	Moderately expensive	Retains heat better and stronger than any other plastic; the poor transmittance may slow plant growth
Single-paned glass	1.13	0.85	Least expensive glass glazing	Retains less heat than any other glass glazing, weak unless it's tempered, too weak for long spans, loses more heat than it gains through heating season
Double-paned glass	0.52	0.74	Fairly expensive	Most common glazing in permanent sunspaces, should always be tempered, most commonly available in 76" length
Triple-paned glass	0.36	0.70	About 30% more than double glass	Provides better insulation but lower transmittance than double glass, could slow plant growth, sometimes difficult to find in Montana
Double low-iron glass	0.51	0.82	Expensive	Difficult to find in Montana
Double glass with one layer of high-transmittance film	0.36	0.66	Expensive	Retains heat well and provides good transmittance
Double glass with two layers of high-transmittance, low-emittance film	0.26	0.63	Expensive	Excellent for retaining heat, provides less transmittance than double glazing, which could slow plant growth

Plastic Glazing

For a low-cost, portable sunspace, plastic or polyethylene glazing might work. Polyethylene is the least expensive glazing, but it usually needs to be replaced in six months. Acrylics, polycarbonates, and fiberglass-reinforced plastics have drawbacks, too. They wear out with time, scratch and puncture easily, and eventually have to be replaced.

Glass Glazings

An attractive, permanent solar addition that's to be an appealing part of your home requires at least double-paned, tempered glass. Double-paned, tempered glass, such as patio-door inserts, transmits about 70 percent of the light that strikes it. Special glass with low iron content allows up to 82 percent of the sunlight through–but it's expensive.

Films

In the past few years, glass manufacturers have started marketing glazing films for glass. One kind of glazing film is a high-transmittance coating, shown in figure 6, that allows more solar gain in sunspaces than does uncoated glass. Another is low-emittance (Low-E) film. It reflects the heat emitted by warm objects, such as walls and floors, back into the room. Low-E film keeps more heat inside than does glass without film. Since double-paned glass with Low-E film is only 15 to 25 percent more expensive than standard double glazing, it may be worth the cost.

Glazing Insulation

An ideal solution for reducing heat loss through glazing is combining high-quality glazing with nighttime insulation. As figure 7 shows, double glazing with insulation, such as a window quilt, pop-in panels, or heavily-insulated curtains, has a significant heat gain all winter. Install a window quilt or other insulation with an "R-value" of at least R-3. R-value is a measure of a material's resistance to heat flow, and, the higher the R-value, the better the insulating qualities. For example, an R-2 window quilt would lose heat twice as fast as an R-4 quilt. Be sure your window insulation can be sealed snugly around the edges to prevent cold air from entering. The Department of Natural Resources and Conservation (DNRC) has a publication, *Window Insulation: How to Sort Through the Options*, that explains the energy benefits of window coverings, and could help you choose appropriate insulation.

Vertical and Tilted Glazing

One question often asked by sunspace builders is "How much should I tilt the glazing to maximize solar gain?" In Montana, there's no need to tilt the glass–vertical glazing is just fine. Tilted glass does receive about 15 percent more sunlight than does vertical glazing, but the problems may more than offset the small increase in solar gain. In fact, most of the extra heat tilted glazing transmits comes in summer, when overheating is your major worry. Finding insulating shades for tilted glazing is difficult, as are installing and operating them. Further, some glazing manufacturers won't warranty glass installed at an angle, and it's hard

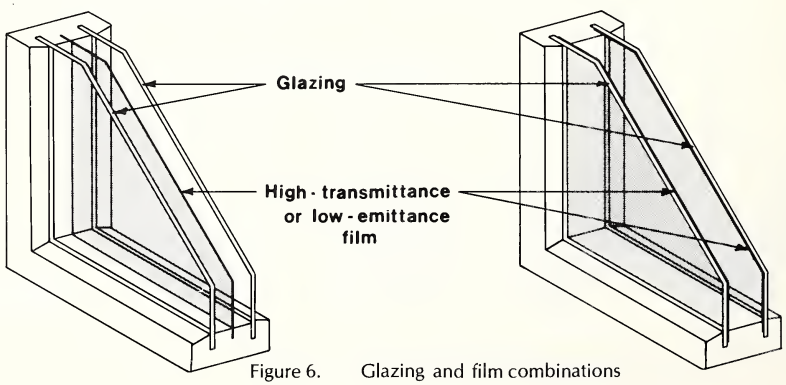

Figure 6. Glazing and film combinations

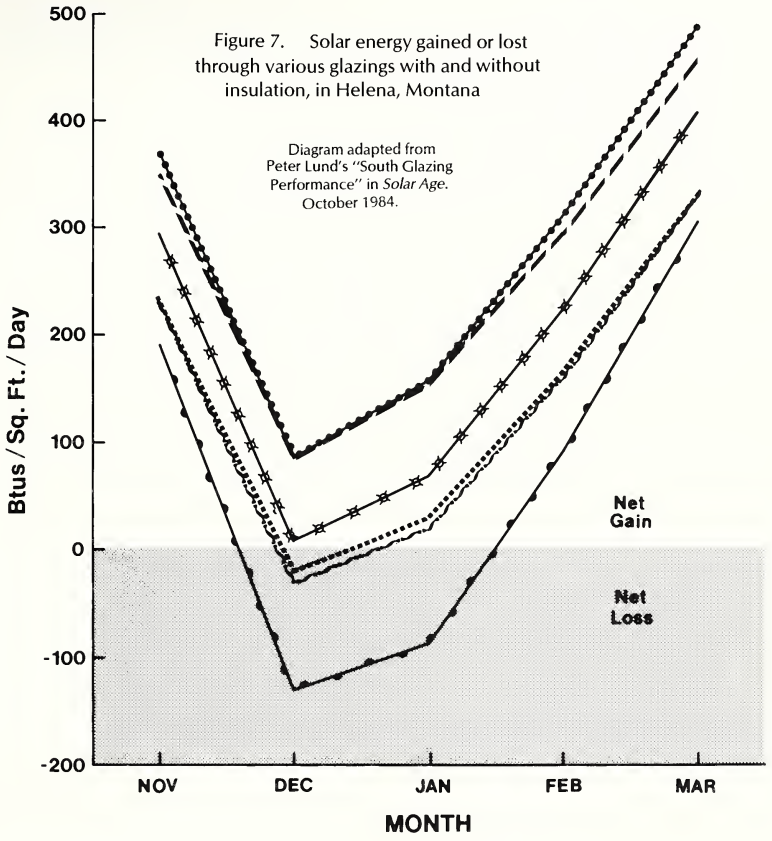

Figure 7. Solar energy gained or lost through various glazings with and without insulation, in Helena, Montana

Diagram adapted from Peter Lund's "South Glazing Performance" in *Solar Age*. October 1984.

Key to Graph

- Double glazing with R-3 nighttime insulation
- Double glazing containing two layers of high-transmittance film
- Double glazing containing one layer of high-transmittance film
- Double glazing containing one layer of Low-E film
- Standard triple glazing
- Standard double glazing

This graph shows the energy efficiency of different combinations of glazing, Low-E films, and nighttime insulation during the heating season in Helena. Lines on the graph above the shaded area show the sunspace gains more heat during the day than it loses at night. The vertical axis of the graph (Btus/ft^2/day) measures the usable solar gain for the sunspace.

The graph shows that standard double glazing without night insulation in a Helena sunspace would lose more heat than it would gain from late November through mid-January. Nighttime insulation on the double glazing would make the most efficient possible system, as shown by the top line on the graph. If you don't use nighttime insulation, then double glazing with a Low-E or high-transmittance film is probably a good investment.

to seal it from rainwater and melting snow. Finally, building with tilted glazing requires special skill.

If your prefab sunspace has tilted glazing, or you prefer its appearance over that of vertical glazing, avoid problems by dealing only with reputable and experienced manufacturers and contractors. Be sure that a prefab sunspace is well sealed against water, and that you can install window shades, nighttime insulation, or insulated curtains.

THERMAL MASS

Once you've figured out the best way to capture sunshine in your sunspace, how do you store the solar energy? Thermal mass is material that absorbs and retains heat. It will absorb heat when the sun is shining, and, when the air temperature falls below that of the thermal mass, heat will flow from it into the cooler air. In addition, thermal mass helps moderate the temperature of your sunspace by holding on to excess heat until it's needed.

Without adequate thermal mass, the solar heat that enters your sunspace has nothing to absorb it, and may overheat the room during the day. Also, the sunspace will cool too rapidly at night.

Masonry (brick, blocks, and rocks), concrete, and water are good thermal masses. Water holds more heat than any other material except a few rare salts that are too expensive to be in general use. Probably the easiest way to provide thermal mass for your sunspace is to build with brick, rock, or concrete.

How much thermal mass do you need? It depends on what material you use. The following table gives rough guidelines about how much masonry, concrete, or water you'll need for thermal mass.

Table 2. Guide for Sizing Thermal Mass

If your south glass equals this percentage of your floor area...	...then you'll need this much masonry or concrete per square foot of glass...	...or this much water per square foot of glass
Percentage	**In cubic feet**	**In gallons**
0 - 5	0.0 - 0.1	0.0 - 0.3
5 - 10	0.2 - 0.5	0.3 - 1.5
10 - 15	0.6 - 1.0	1.5 - 2.5
15 - 20	1.1 - 1.5	2.5 - 3.8

Here are some things you should know about thermal mass.

- As figure 8 shows, the floor and back wall of the sunspace can act as thermal mass if built of appropriate materials, so they should receive as much sunlight as possible. For the back wall to get direct sunlight, keep about 10 to 14 feet between the back wall and the glazing, and you'll still have enough room to enjoy your sunspace. A six-inch-thick concrete or masonry floor or wall will perform well as thermal mass.
- Water has been less popular because it's sometimes messy, although it stores about three times as much heat per pound as masonry. New designs in water containers, including water tubes, may make water easier to use as thermal mass in the future.
- In greenhouses, soil in plant containers and gravel walkways between planting beds also act as thermal mass.

INSULATION

Using a window quilt or other nighttime insulation is the best way to reduce energy loss in a sunspace, because most sunspace heat is lost through the glazing. Heat will steal away through cracks and inadequately insulated walls and ceilings; therefore, you should insulate those parts of the sunspace as well. An R-value of 20 should be sufficient for the sunspace walls and ceiling.

Make sure your sunspace is as tight as possible—air leaks rob heat. Caulk and weatherstrip around the glazing, doors, vents, windows, and anywhere else that might let warm air out of the sunspace. Tom Harpole of Avon, who built a solar greenhouse, recommends that you "seal your sunspace as tightly as if you were building a boat." Be especially careful to caulk around the edges of the glazing—the most common source of air

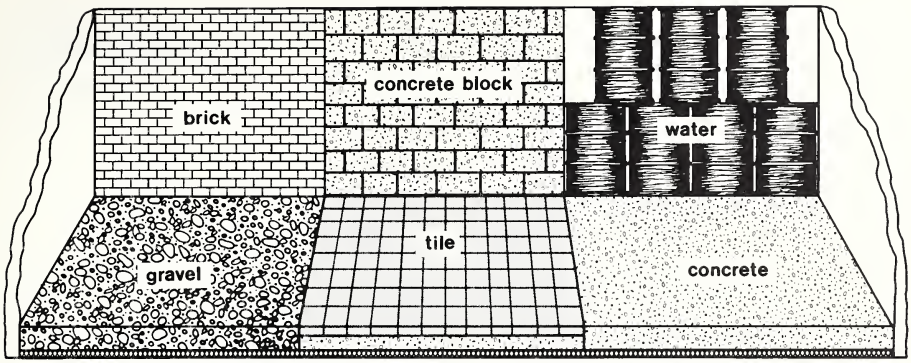

Figure 8. Possible thermal masses for use in floors and walls

leaks. Even tiny cracks can lead to major heat loss, so be sure that your sunspace construction is tight. Figure 9 shows sunspace areas that are especially prone to heat loss.

Outside the sunspace, the foundation wall must be insulated, and it's probably a good idea to run a band of insulation under the perimeter of the sunspace slab. The foundation wall requires two inches of extruded polystyrene (Styrofoam or blueboard) from above the ground down to the frost line, which is three to four feet deep in Montana. A less expensive alternative is to use expanded polystyrene (beadboard or snowboard) instead of the Styrofoam, but beadboard absorbs water and will need to be covered with a four-mil-thick polyethylene vapor barrier. If you decide to insulate under the sunspace slab, you need a two-to-four-foot-wide band of rigid styrene insulation under the slab perimeter. Figure 10 shows the necessary two inches of insulation on the foundation wall and an optional two-to-four-foot-wide band of insulation under the sunspace slab.

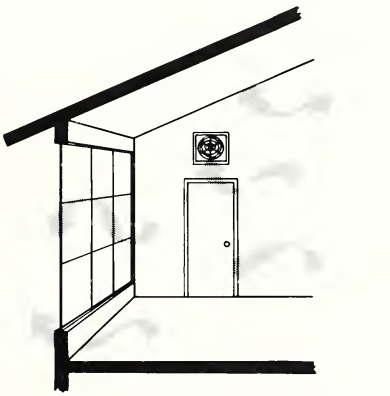

Figure 9. Potential heat loss areas

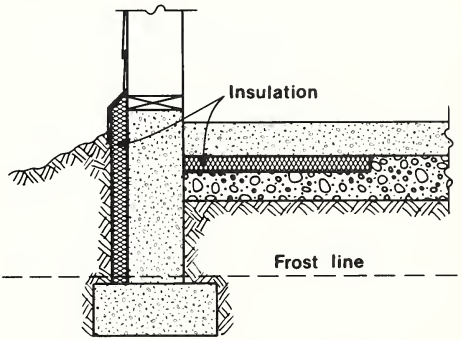

Figure 10. Example of sunspace foundation and slab insulation

HEAT DISTRIBUTION

One benefit of a well-designed sunspace is that it can collect and store more heat than is needed for warming the sunspace. The extra heat can be distributed to the rest of your house to reduce winter heating bills.

Heat can be distributed from your sunspace in a number of ways. Usually, heat goes into the house through the wall that's shared by the sunspace and the house. An uninsulated masonry common wall is good for both collecting and distributing solar energy from a sunspace. However, most Montanans live in wood-frame houses, and heat doesn't conduct through frame walls as readily as through masonry walls. Some of the heat stored by the common wall will conduct into the rest of your home, but you'll need to provide additional air circulation between the wall and the sunspace to help move the heat. Connecting doors and windows are one way to do it. If you attach your sunspace to an insulated wood-frame wall, you'll have to be more enterprising in distributing your sunspace's heat—a venting system is necessary.

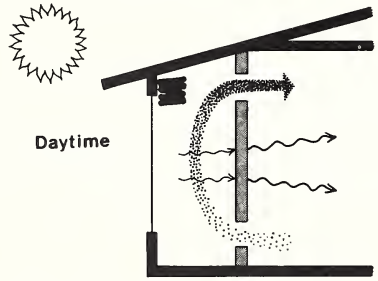

Figure 11. Air circulation with vents open between the sunspace and house

The most efficient way is to build some vents low in the wall and others high in the wall. Figures 11 and 12 show how a venting system regulates air flow. Heated air comes into the house through the upper vents; cool air leaves the house and enters the sunspace through the lower vents.

Making the vents the right size is important. If you use both doors and windows for venting, you'll need at least 8 square feet of vents in the common wall for every 100 square feet of glazing in the sunspace. If you have high and low vents in the wall, you need only 3 square feet of vents for every 100 square feet of glazing. To prevent heat loss, the vents must be closed at night. Otherwise, hot air will go out the top vents and heat the sunspace, while cool air from the sunspace will flow into the house from the low vents. You can buy passive vents that automatically close to stop this reverse air flow.

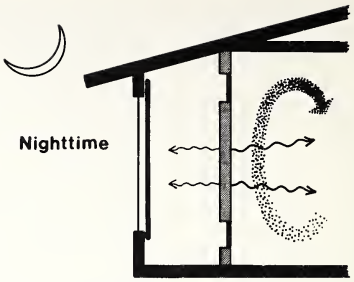

Figure 12. Air circulation with vents closed and window covering in place

Many quiet ventilation fans are made specifically for sunspaces, and can be connected to a thermostat to automatically move warm air from the sunspace into the house. These fans work the same way the blower on your furnace operates.

BUT WHAT ABOUT SUMMER?

Even in Montana, summer temperatures soar into the 90s and sometimes over 100 degrees. Especially in the eastern part of the state, summer afternoons can be blisteringly hot. The last thing you need in the summer is more heat. Fortunately, there are ways to keep your sunspace from turning your home into a summer sauna.

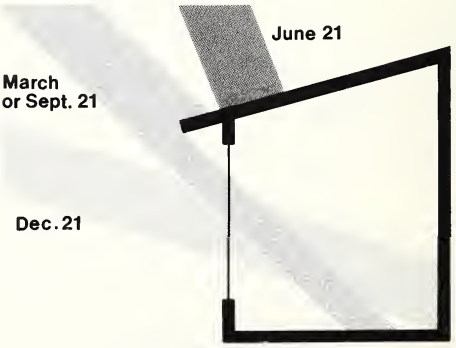

Figure 13. An overhang's effect on seasonal sun angles

If your sunspace has vertical glazing, you can add an overhang for shading. In summer when the sun is high in the sky, the overhang should prevent overheating. Figure 13 shows that, in winter, the sun is low enough in the sky for its rays to enter the sunspace under the overhang. An overhang that extends 1-1/2 to 2 feet past the glazing should do the trick.

It's not easy to build an overhang large enough to shade tilted glazing. If you have tilted glazing, you can use movable shades, awnings, or reflective drapes to shade the sunspace and combat overheating. Window quilts with special insulating layers and a vapor barrier work well in both winter and summer.

Be careful when using insulating window coverings, such as those shown in figure 14, for shading. Heat can build up between the glazing and the curtain on a sunny day if the curtains are sealed tightly along the edges. The glass will shatter if the temperature gets too high. To prevent this, use shades with white or silvered backing, so that most of the light coming between the glazing and curtain will be reflected back outside before it separates into heat waves. Even window treatments with these reflective coatings should have air circulation behind them to prevent heat buildup and condensation.

Ventilation is essential for summer cooling of your sunspace, and no amount of shading will substitute for it. Vent size to the outside should equal about 10 percent of the south glazing. Double the vent area to the outside if your sunspace is a greenhouse, since the humidity from the plants will make it muggy.

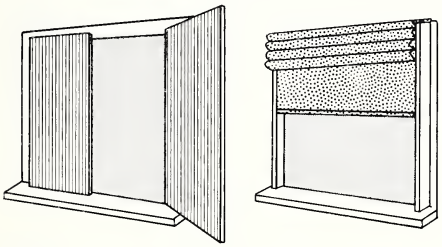

Figure 14. Insulating shutters and shades

If you supplement the ventilation with a fan, the minimum fan capacity should be 5 cubic feet per minute for every square foot of glazing. Increase your ventilation and fan capacity by 30 percent for tilted glazing. *Solar Age* and *New Shelter* magazines have information on the vents, fans, and other equipment available for sunspaces.

IS IT ALL WORTH IT?

Worksheets are provided on the following pages to give you a rough idea of how much solar heat can be captured with different materials. Construction materials vary widely in price. With an idea of the solar gain, you can weigh the benefits against the costs of materials.

No matter how you calculate it, there are certainly better ways to save energy than building a sunspace. Investing the money in insulation, caulking, weatherstripping, a set-back thermostat, and water heater insulation all make more sense if energy savings is your major goal. A sunspace will probably save you no more than 10 to 15 percent on your annual heating bills (see the worksheets at the end of this guide). Saving that 10 to 15 percent could cost you $5,000, $10,000, or more.

On the other hand, a cozy sunspace may increase your home's desirability to possible buyers, and they may be willing to pay more for the house than if you hadn't added the sunspace. If you want more living space—and you were going to build an addition anyway—sunspaces are no more expensive than traditional rooms, but they're sunnier. Gardening, relaxing in a hot tub, or soaking up sunshine in a room you built yourself might make bitter cold winters seem less harsh and turn your house into the home you've always wanted.

SOLAR GAIN WORKSHEETS

The following provides a way to roughly calculate how much heat your sunspace could gain. Many factors, such as wind velocity, shading, the cleanliness of glazing, the number of air leaks in your home, and the amount of insulation you have, are not allowed for in this calculation. Your actual heat gain depends on individual circumstances, and could be calculated precisely only with a computer.

The calculations here will help you compare the different construction materials and decide if their cost is worth the possible energy savings and other benefits. The numbers used here are representative of much of Montana's climate, but not necessarily accurate for your sunspace. They are intended only as estimates to help you in the design process.

1. HOW MUCH GLAZING DO I HAVE?

First, find the total area of the south-facing glass on your sunspace, excluding framing. To determine this, measure the width and length of the exposed glass surface (don't include framing).

Example: A sunspace in Missoula has four panes of glazing, each measuring 5 feet by 6 feet, or 30 square feet (ft^2).

$$6 \text{ ft} \times 5 \text{ ft} = 30 \text{ ft}^2$$

$$4 \times 30 \text{ ft}^2 = 120 \text{ ft}^2$$

2. HOW EFFECTIVE IS MY GLAZING AT THE TRANSMITTANCE OF SOLAR ENERGY?

Multiply the glass area by the value given it in table 3. This number represents the amount of heat transmitted through glazing. Note: this calculation assumes that, once the heat is in your sunspace, none of it will be lost through air leaks or infiltration.

Example: The Missoula sunspace has triple glazing.

$$120 \text{ ft}^2 \times 0.70 = 84.0$$

Table 3. Transmittance Values for Various Glazings

Double glazing with two layers of high-transmittance, Low-E film	0.63
Double glazing with one layer of high-transmittance, Low-E film	0.66
Triple glazing	0.70
Double glazing	0.74

3. HOW MUCH SUNLIGHT IS THERE IN MY AREA?

Multiply your product, which is the number representing the heat that comes through your glazing, by the average winter insolation in your area, shown in table 4. Average winter insolation is measured in British thermal units (Btus); one Btu is the amount of heat required to raise one pound of water one degree Fahrenheit. These numbers apply to vertical glazing and are accurate for the months of November through March. This calculation tells you about how many Btus you gain each day.

Table 4. Average Winter Solar Insolation for 21 Montana Sites

Site	Avg. Insolation ($Btu/ft^2/day$)	Site	Avg. Insolation ($Btu/ft^2/day$)
Anaconda	830.8	Havre	932.9
Billings	1,016.7	Helena	985.7
Bozeman	899.0	Kalispell	639.5
Browning	998.4	Lewistown	1,021.4
Butte	922.4	Libby	578.9
Choteau	947.1	Miles City	1,014.4
Dillon	1,073.7	Missoula	796.7
Ennis	981.6	Polson	622.0
Glasgow	967.4	Thompson Falls	589.6
Great Falls	946.3	West Yellowstone	922.1
Hamilton	981.6		

SOURCE: *Solar Data Manual,* 1985.

Example: As shown in table 4, Missoula has an average winter insolation of 796.7 $Btus/ft^2/day$.

$$796.7 \text{ Btu/ft}^2\text{/day} \times 84.0 = 66{,}922.8 \text{ Btus/day}$$

The Missoula sunspace gains only 78 percent of the Btus the same sunspace in Billings would. As shown below, the same sunspace in Billings would gain an average of 71,382.5 Btus on a winter day.

$$1{,}016.7 \text{ Btu/ft}^2\text{/day} \times 84.0 = 85{,}402.8 \text{ Btus/day}$$

4. HOW MUCH HEAT WILL THE SUN PRODUCE IN WINTER?

In Montana, the heating season runs from October to April. Since you know the average number of Btus you gain each winter day, multiply it by 213 days. Now you know the heat gain in Btus over the heating season in an average year.

Example: In Missoula, as in all of Montana, the heating season is 213 days.

66,922.8 Btus/day x 213 days =
14,254,556 Btus/heating season

5. HOW MUCH HEAT DOES MY THERMAL MASS STORE?

To allow for the efficiency of your thermal mass, multiply the number in the second column of table 5 by the answer you got in step 4. Without thermal mass, only about 75 percent of the solar energy that enters the sunspace will provide heat. A four-inch-thick concrete floor would put 90 percent of the solar gain to work for you.

Table 5. Heat Storage Capacity of Several Thermal Masses

Thermal Mass	Factor of Solar Use
None	0.75
4" concrete slab floor	0.90
Slab floor and masonry common wall	0.95

Example: The Missoula sunspace has a concrete slab floor.

14,254,556 Btus x 0.90 =
12,829,100 Btus/heating season

6. HOW MUCH FUEL WILL THE SUNSPACE SAVE?

To translate thermal gain into the amount of heating fuel it could replace, divide the Btus by the heat content of your current fuel, shown in table 6. This number takes the inefficiency of your heating system into account.

Table 6. Effective Heat Content of Different Fuels

Fuel	Effective Heat Content	
Electricity	3,413	Btus/kilowatt hour (kWh)
Natural Gas	700,000	Btus/thousand cubic feet (mcf)
Fuel Oil	100,000	Btus/gallon
Propane	64,000	Btus/gallon
Wood	9,000,000	Btus/cord

Example: The Missoula home has an electric furnace.

12,829,100 Btus ÷ 3,413 Btus/kWh = 3,758.9 kWh

The Missoula home will save about 3,758.9 kWh per year. With a gas furnace, the Missoula sunspace would save about 18 mcf of natural gas each year.

7. HOW MUCH MONEY WILL THE SUNSPACE SAVE?

With the rough estimate of heating fuel saved, you can estimate the amount of money a sunspace could save over one year at present energy prices. Multiply the units of fuel by its cost per unit.

Example: Currently, electricity costs $0.045 a kWh; the annual savings for the Missoula sunspace is $169.15.

3,758.9 kWh x $0.045/kWh = $169.15

Heating fuel costs vary in Montana between seasons and depending on which utility serves you. Prices also change over time. Your utility company can give you the current cost for your fuel. Based on recent Montana Power Company costs, the Missoula sunspace would save between $70.00 and $80.00 annually if natural gas were the home's fuel.

LIVING WITH SUNSPACES

Hank Smit, a contractor in Helena, built his two-story sunspace, with the help of a grant from the Department of Natural Resources and Conservation. The heat that rises naturally to a second-story open loft is circulated by a ceiling fan, and forced into an opening in the top of the loft that directs warmed air to the back of the house.

Some people build sunspaces for fun. Lewis and Frances Higinbotham of Missoula bought a house with a good south-southwest exposure, with enough leafy trees in the yard to shade their combination greenhouse-sunspace-spa in the summer. Their sunspace has a gravel floor and water in 55-gallon drums for thermal mass. They plan to paint the masonry on their house a darker color to absorb more heat. The cost of running the spa offsets their heat savings, but they think their enjoyment of the spa is worth the cost.

Rich and Gigi Moy of Helena sited their south wall 13 degrees east of magnetic south, giving them optimum solar gain and a great view of Helena. A garage on the west side of the house protects the house from prevailing west winds. A massive stone fireplace doubles as a thermal mass, gathering sunlight from the south windows. The home is weatherproofed by airlock entryways, triple-glazed windows, and plenty of insulation in the ceiling and walls.

Moy added a two-story sunspace and greenhouse that circulates solar energy to the rest of the house by both natural distribution and vents and fans. Soil and concrete in the greenhouse act as more thermal mass, storing heat to be released to the room slowly. Moy describes his home as a "fun place to live" and insists solar is "absolutely the only way to go."

Angie Leprohon and David Nimick's unique sunspace design was featured in *New Shelter's* October 1982 issue. The Helena couple decided they didn't want to have a sunspace heating their home year-round, so they built portable sunspace panels that enclose their front porch in the fall and winter. In the spring, when the days get longer, David and Angie take the sunspace down and store it for the summer.

Mike and Mabelle Hardy of Missoula say their sunspace's temperature has never been below 52 degrees, even in sub-zero weather. The Hardys' energy efficient house has four inches of polystyrene insulation in the basement, and insulation with a polyethylene vapor barrier envelopes the home. An air-to-air heat exchanger and vents in the sunspace bring in fresh air when it's needed. Window quilts along the south glazing keep warm air inside. Hardy advises people to "talk to your architect" before building, so that you'll both know what you want from the beginning.

Gary and Sharon Willis of Helena use their sunspace to heat their home. It's an attractive room with handsome furniture and decorative, heat-absorbing tile. The sunspace adds to the market value of the home. The sunspace opens to the kitchen area by a door, and air naturally circulates between the main home and sunspace. A fan sends accumulated heat to the basement, and several vents to the outside along the bottom of the glazing cool the room in the summer, when overheating could otherwise be a problem.

Hal and Jean Stearns of Helena have a sunspace on their first floor combined with a solar collector wall on the second floor to pull more heat into their home. Vents and fans circulate the heat to the north side, where it's needed most. The Stearns enjoy flowers in their sunspace year-round.

Steve and Pam Jackson have a home on the north end of a meadow on Grant Creek in Missoula. The southern exposure is perfect for a sunroom that combines beauty and practicality. They had a problem with their sunspace—the glass glazing didn't quite fit the first time around. The loose fit allowed moisture to build up at the bottom of the windows, and heated air leaked out of the sunspace. The glass had to be replaced. The Jacksons will add awnings this year to keep the room from overheating on clear days. In spite of the expense of replacing the glazing, the Jacksons say they're happy with their sunspace.

Sunspaces pose special problems for mobile homes. A structure adequate to capture and store heat is relatively heavy, and therefore most appropriate for permanent construction. Shading and orientation to the south could be serious concerns in mobile home parks with small yards and restrictive rules about modifications. Sunspaces ideally should be built on an insulated foundation and finished inside. This should be undertaken only if you don't plan to move your mobile home. The actual amount of solar radiation in Montana's climate varies considerably, but should be counted on for no more than about 15 percent of the annual heat load. However, the living space a sunspace provides may be the major value outweighing the relatively small solar gain. If you decide to add on to your mobile home, a sunspace might be a logical choice.

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